Energy Harvesting from Treated Waste Water using Geothermal Heat Pumps

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Outline:

Project Statement

Background Introduction

GHP simulations and economic analysis

Conclusions

Problem Statement

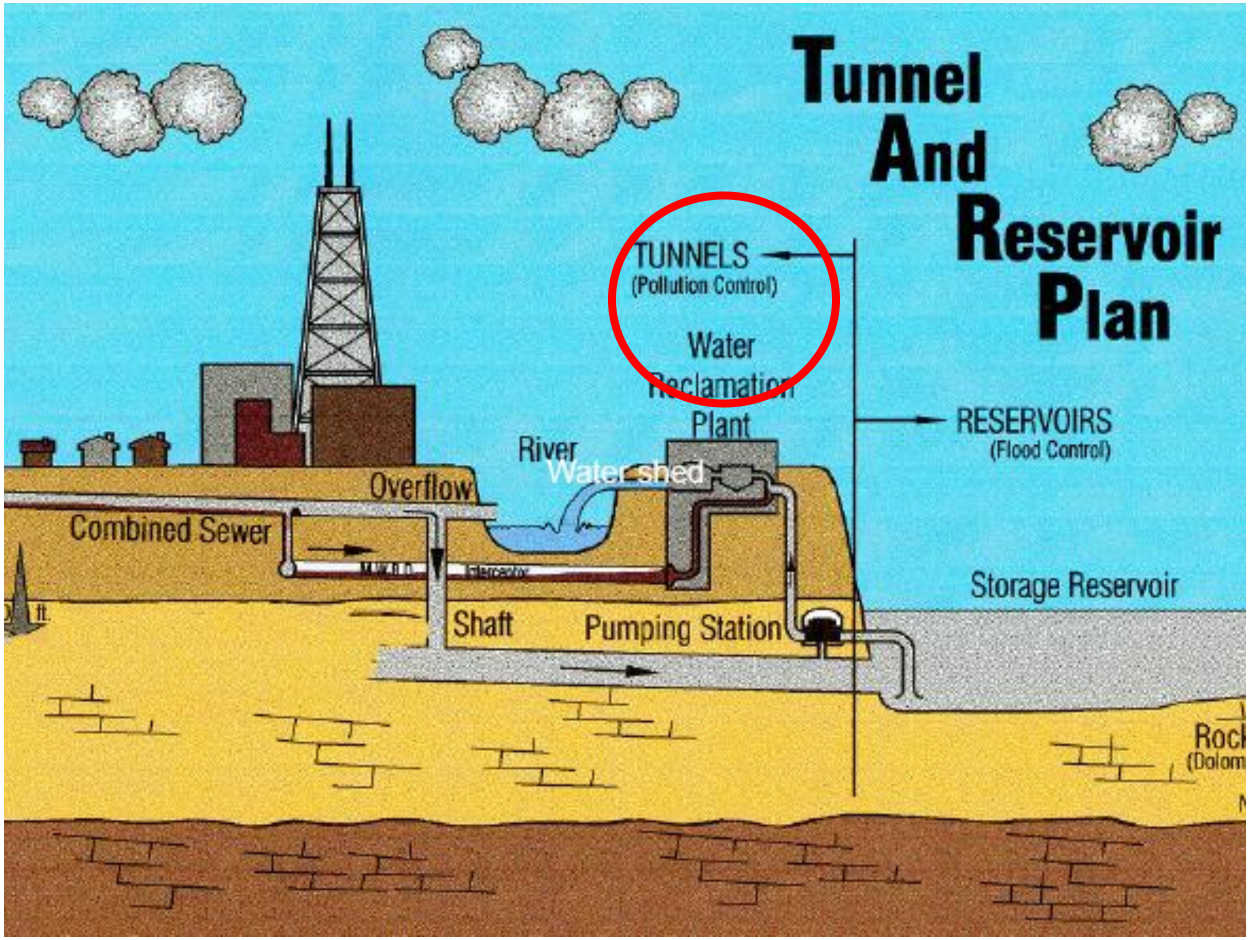
Looking for Alternate Energy:

A New Challenge for Researchers/Scientists

Q: Before we find a revolutionary way to solve our energy problems, how can we maximize our use of current technologies?

A: Geothermal Heat Pump (GHP) + Benefit of Waste Water Temperature

Before We Start: Tunnel and Reservoir Plan of the City



http://www.debrashore.org/pdf/worldwaterday.pdf

Energy Needed in Kirie Plant :

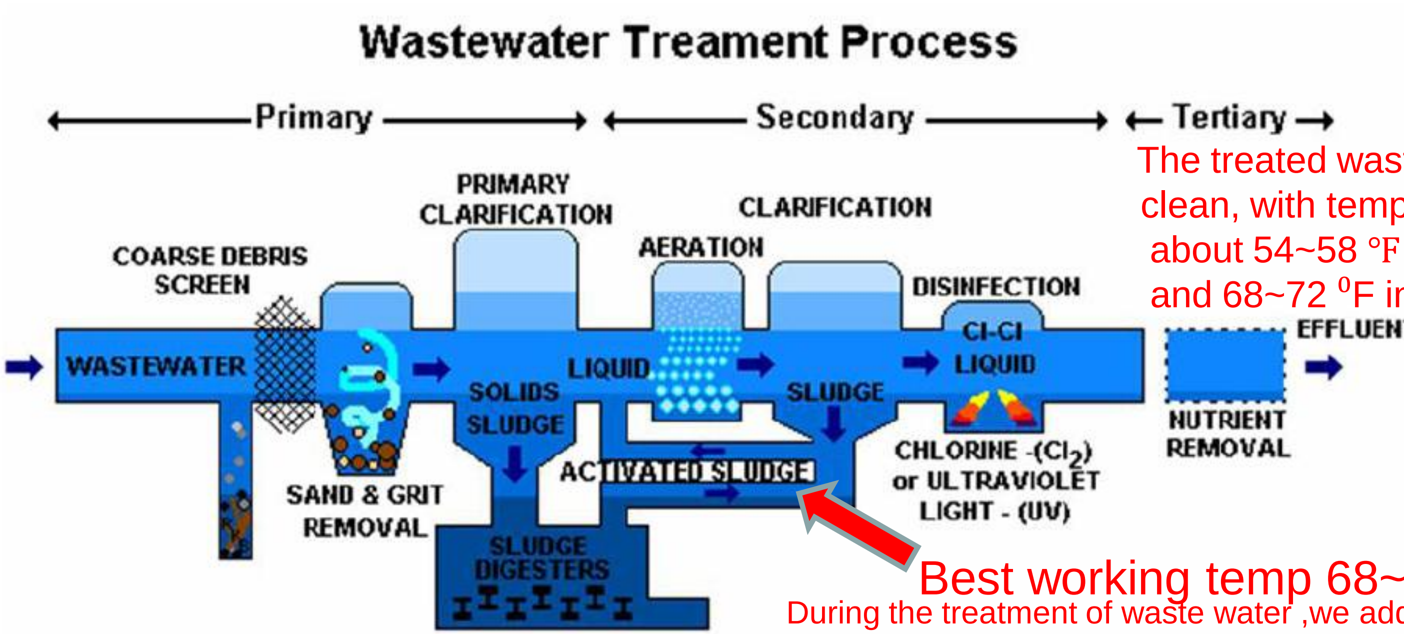
In 2008, the peak monthly **electricity consumption** at the Kirie Water Reclamation Plant (mostly for pumping) was **2.7×10^{6} kWh**, and **51,000 therms of natural gas** was needed in order to meet its energy needs.

A significant fraction of the total energy was utilized for heating and cooling of buildings.

In 2008, the energy consumption costs for the Kirie WRP located in Desplaines, Illinois was **$2.5 Million**.

Background Introduction:

Typical Waste Water Treatment Process



The treated waste water is clean, with temperature of about 54~58 °F in winter and 68~72 ^{0}F in summer

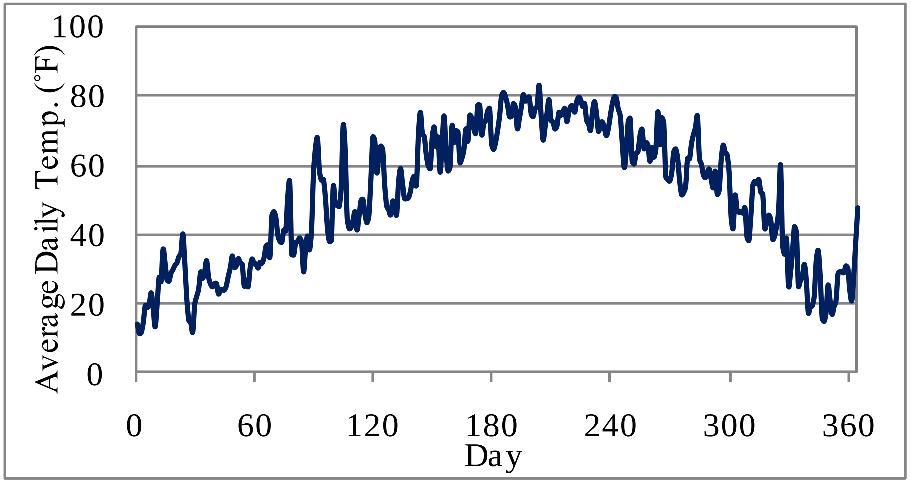
Best working temp 68~95 ˚F

During the treatment of waste water ,we add energy to allow digestion reactions to take place

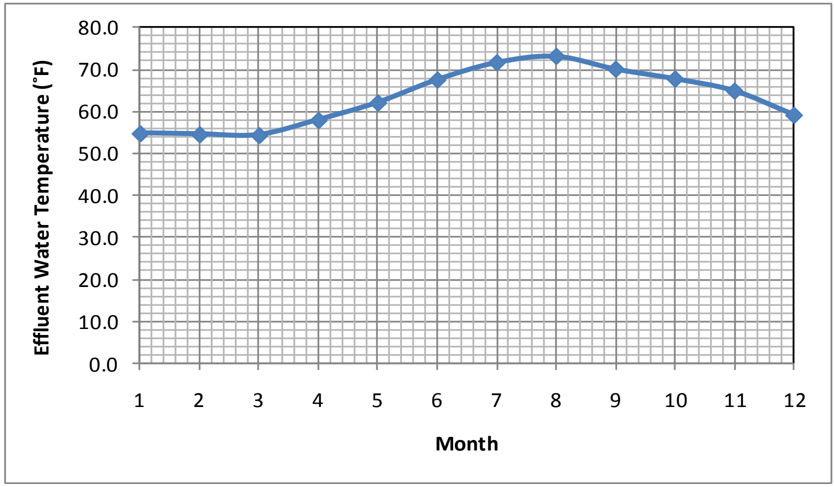
https://www.honeywellprocess.com/library/marketing/whitepapers/MasterLogicPLC-Wastewater.pdf

Chicago—Suitable for the GHP technology

Chicago daily averaged temperature of 2010



Kirie Plant: Measured Effluent Water Temp



– Energy extracted can be used for either heating/cooling the Building, or for pre-heating the waste water in winter before the activated sludge process.

- **Treated water temperature remains constant before release to effluent**
  – Kirie Water Reclamation Plant water temperature
    54~58 ^{0}F in winter,
    68~72 ^{0}F in summer

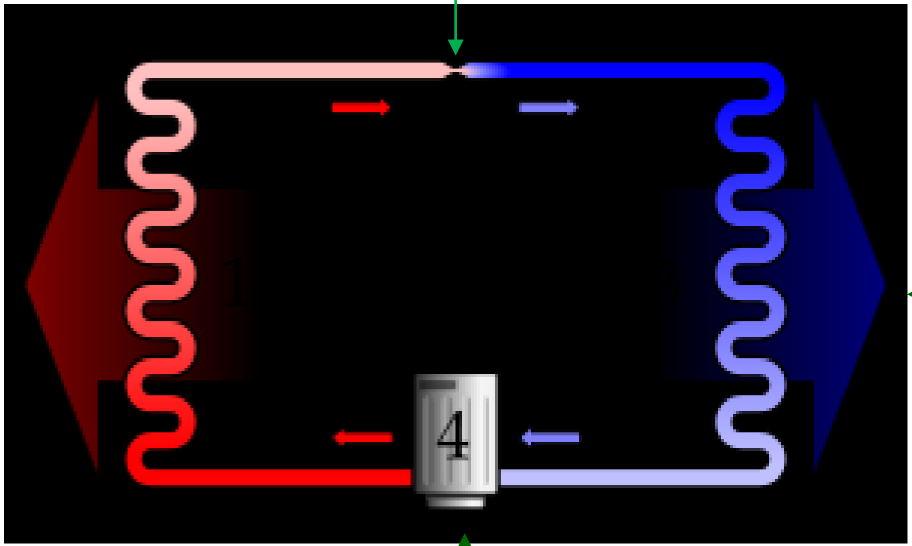
Geothermal Heat Pump (GHP)

Heat pump (HP) – causes heat to flow in a direction opposite to its natural tendency or "uphill" in terms of temperature. The name heat "pump" is used because work must be done (energy consumed) to accomplish this.

Heat Pump
- Expansion valve
- Evaporator
- Compressor
- Condenser

Throttle Valve

High Pressure Side (heat addition)



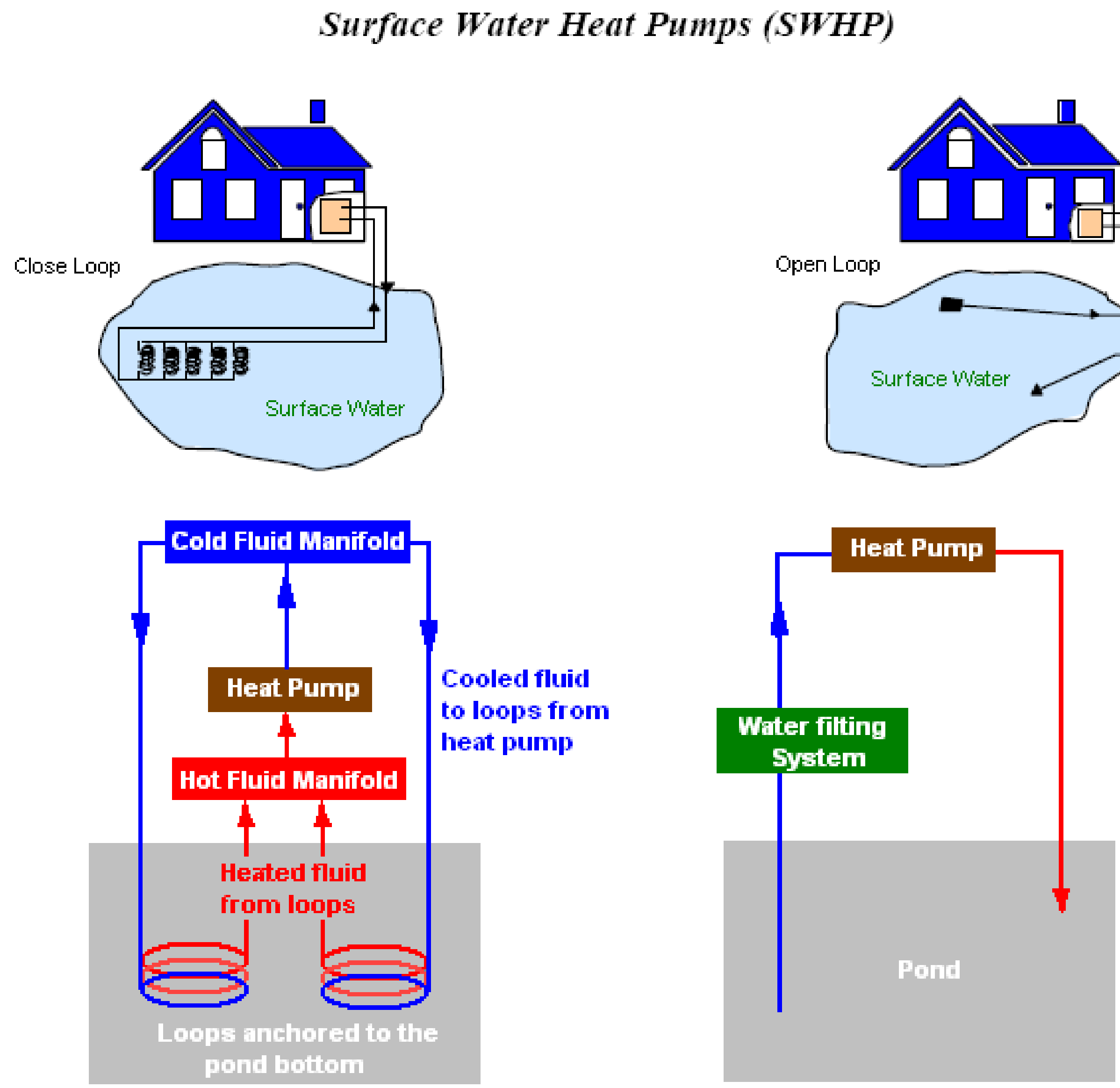
Low Pressure Side (heat removal)

Pump

- Boiling point effect of pressure
- Evaporation at low pressure (T_{low}) – removes heat
- Condensation at high Pressure (T_{high}) – provides heat.
- Compressor increases pressure between evaporator and condenser –only energy consuming part.

Geothermal heat pumps (GHPs) can use the almost constant temperatures of treated water before release to effluent especially to provide efficient heating and cooling.

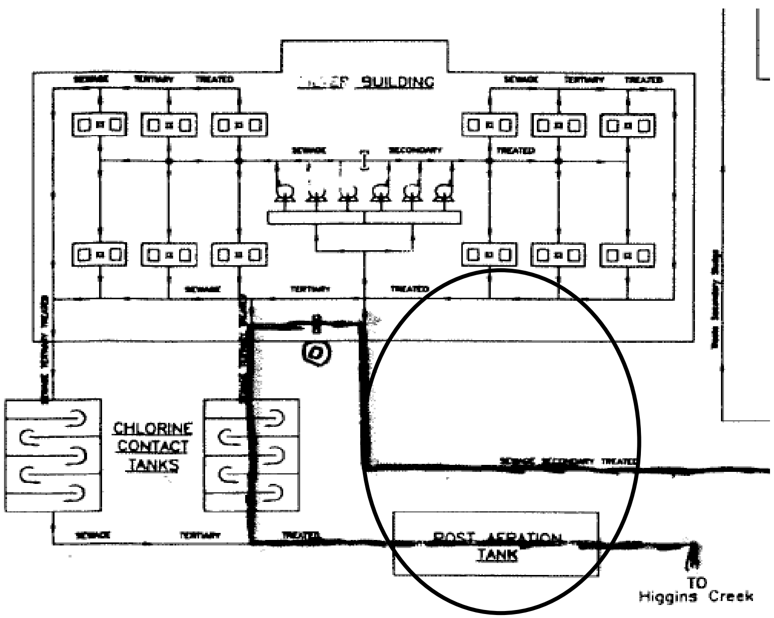
Two surface water heat pump systems:

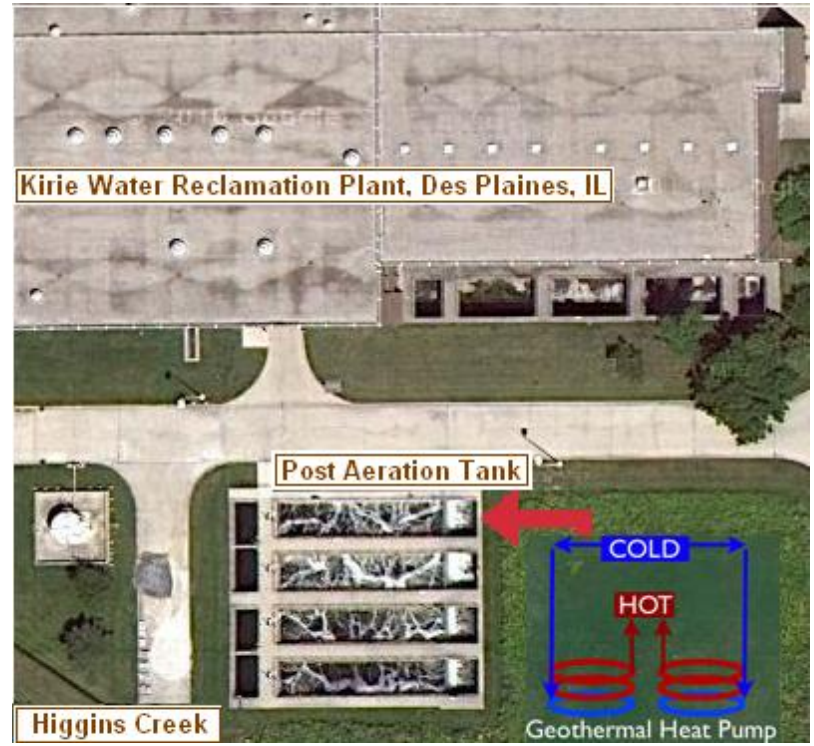


Problems:
Dirt;
Algae/microorganism;
Corrosion;

GHP Design

Kirie Plant: Selected Location for GHP





Hydraulic Profile of the Kirie WRP: designed for an average flow of 52 MGD and has a maximum design capacity of 110 MGD

Geothermal Heat Pump Design

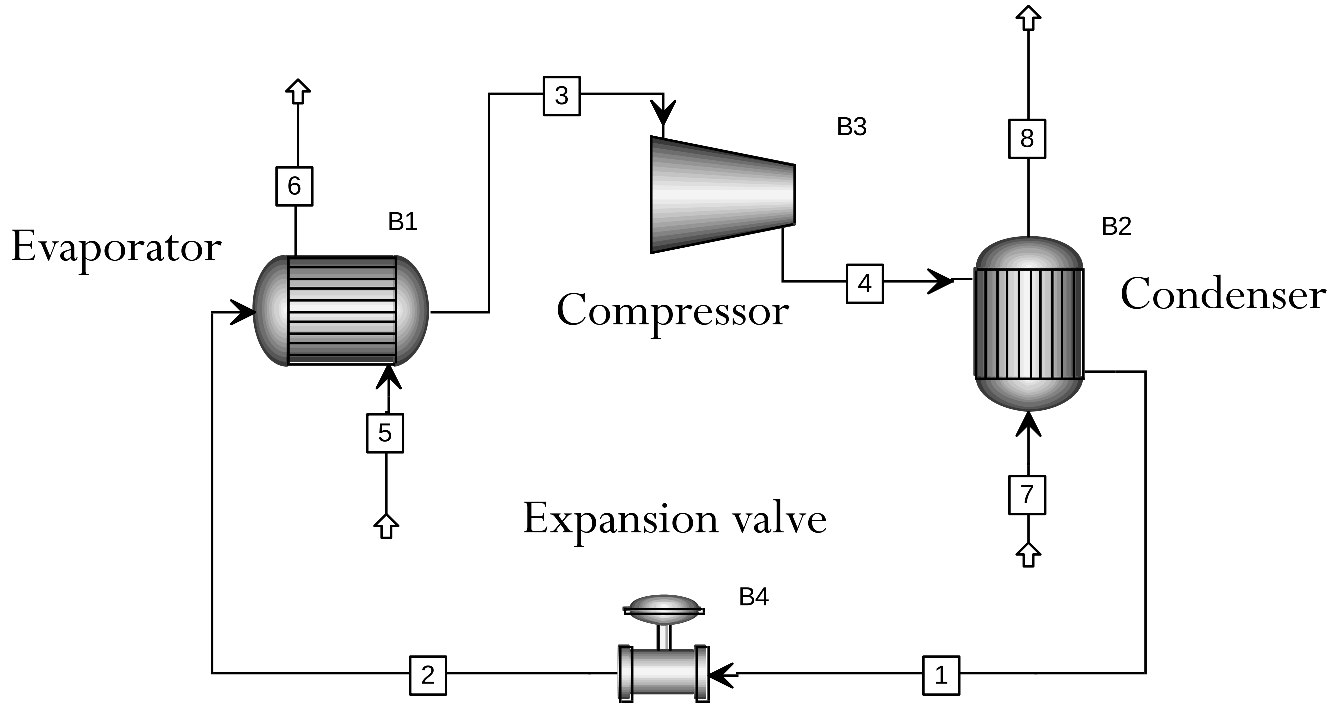
- Design a GHP utilizing treated waste water as energy source
- Compute heating and cooling load
- Maximum heating/cooling load was about 30 tons, use a combination of 5, 10 and 15-ton systems.
- Costing Analysis to compare HVAC and geothermal systems

Design parameters for Heating

- Administration Building at Kirie Water Reclamation Plant was used for collecting pilot data
- The total Flow Rate was computed using 30-ton load

Temperature difference between the outlet and inlet of the GHE , $\Delta T \approx 5^{o}$ F
Administration Building temperature kept at 72^{0} F
Total load = Q_{load} = 30 tons = 360000 Btu/hr = 0.1054 MW
Total Volume Flow Rate = 90 Gal/min

ASPEN Plus Simulation



Streams 1,2,3,4 contains R22
Streams 5,6 contains water from effluent
Streams 7,8 are air flow

ASPEN Plus Simulation

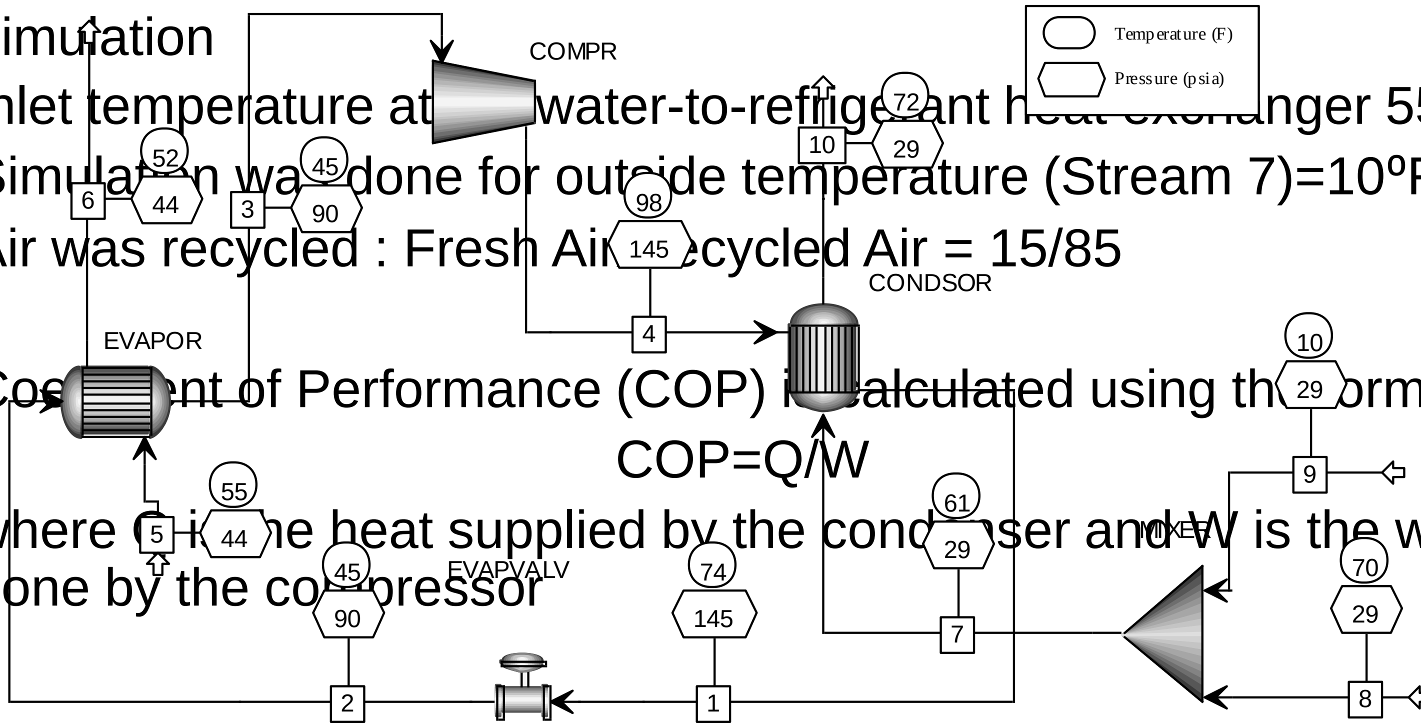
First simulation

- Inlet temperature at water-to-refrigerant heat exchanger 55ºF
- Simulation was done for outside temperature (Stream 7)=10ºF
- Air was recycled : Fresh Air:Recycled Air = 15/85

- Coefficient of Performance (COP) is calculated using the formula

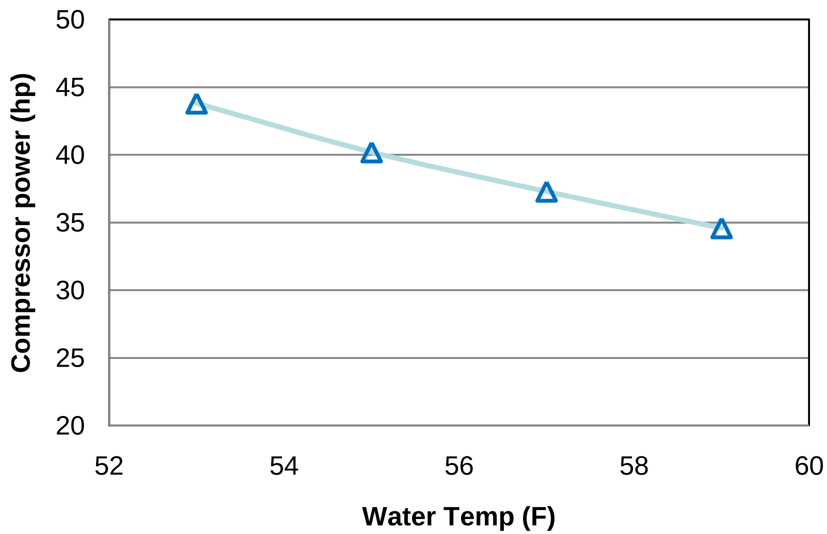
$$COP=Q/W$$

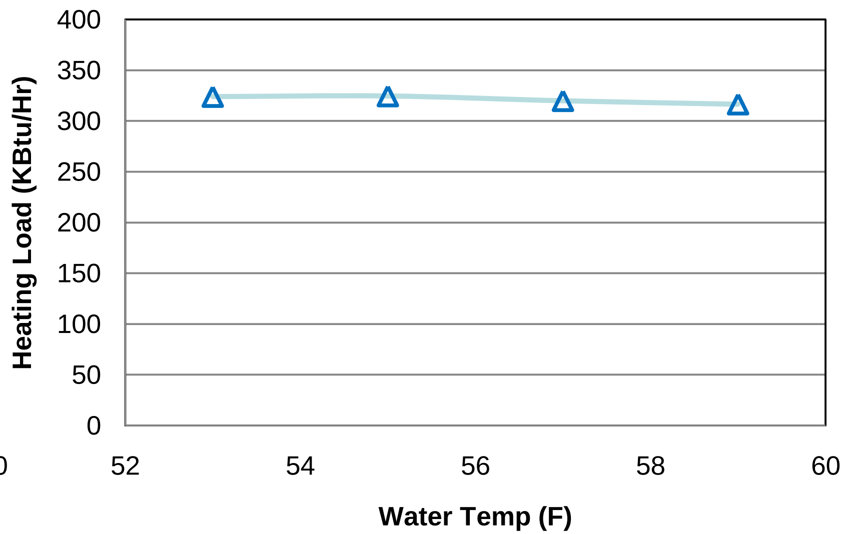
where Q is the heat supplied by the condenser and W is the work done by the compressor

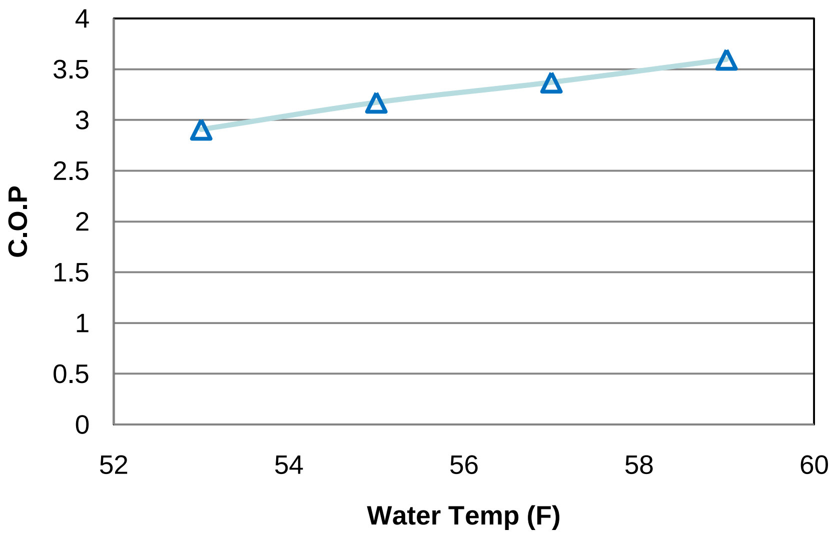


Calculated C.O.P = 3.4

C.O.P change with T_{water} (when fix T_{out}= 20 ^{0}F)

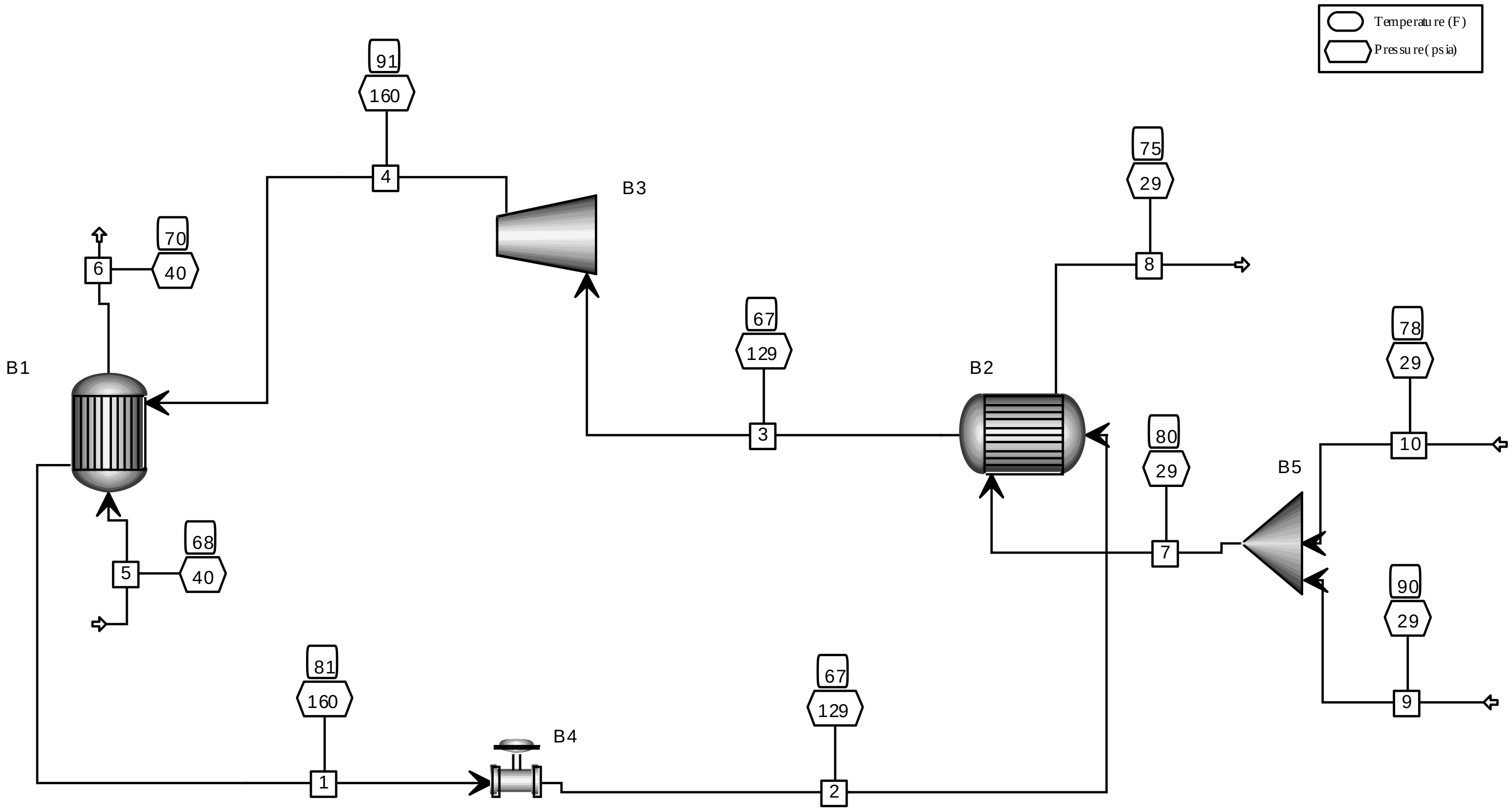






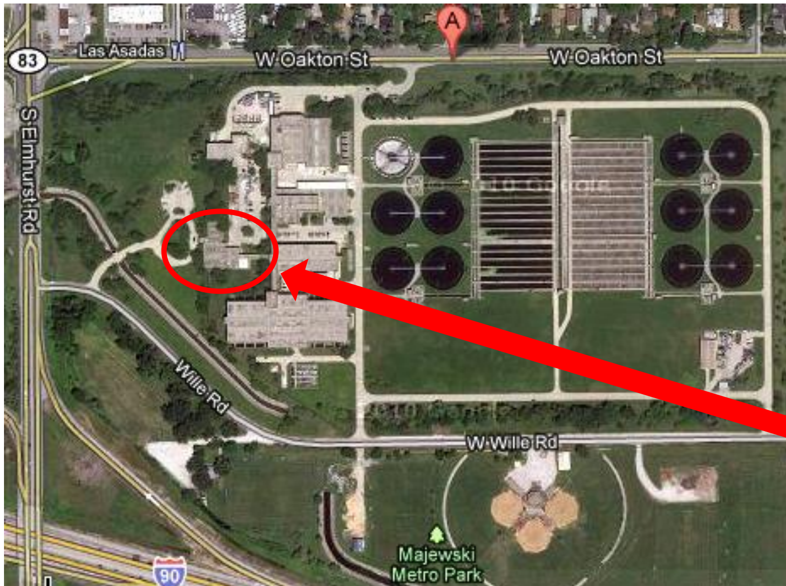
Simulation of Cooling Process

(T_{water} =68 ^{0}F, T_{air}= 90 ^{0}F)



Calculated C.O.P = 2.7

Energy Cost Analysis for the KWRP

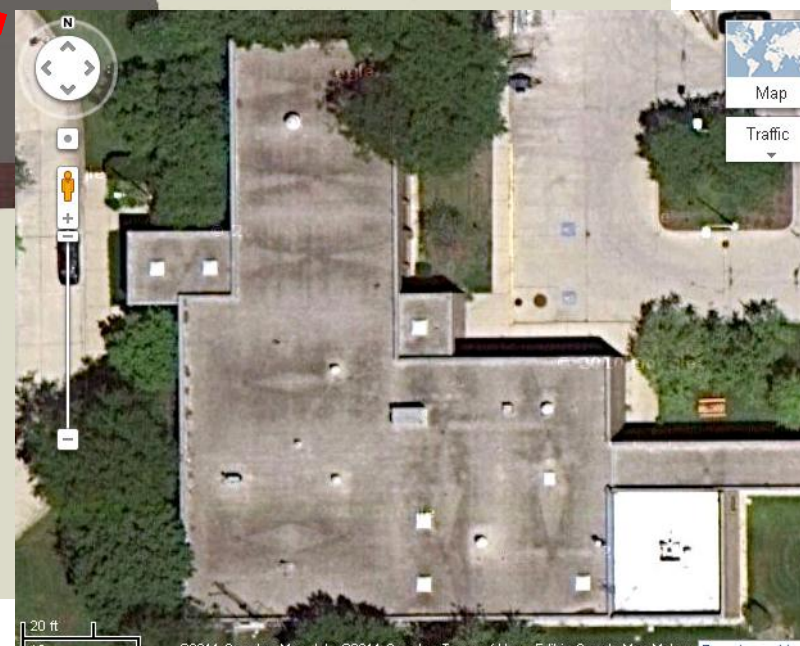


Building Area

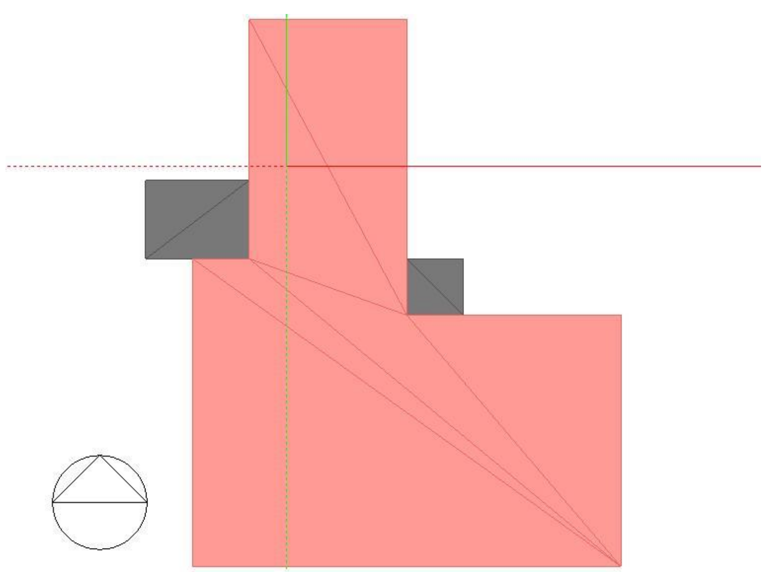
	Area [ft2]
Total Building Area	13829.77

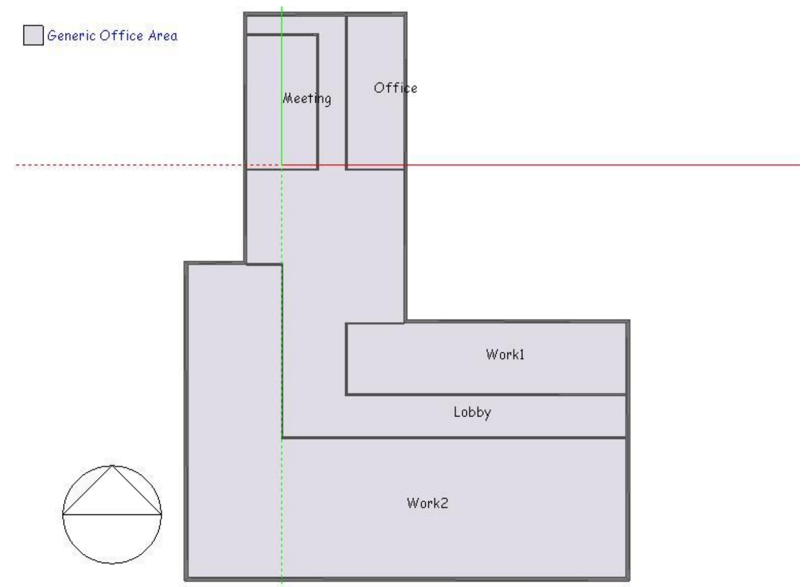
General

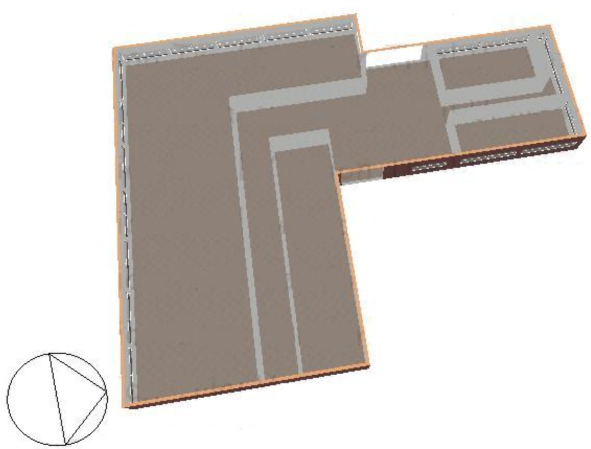
	Value
Program Version and Build	EnergyPlusDLL 6.0.0.023, 9/26/2011 2:05 PM
Weather	JCKWR
Latitude [deg]	41.98
Longitude [deg]	-87.9
Elevation [ft]	659.48
Time Zone	-6.0
North Axis Angle [deg]	0.00
Rotation for Appendix G [deg]	0.00
Hours Simulated [hrs]	8760.00

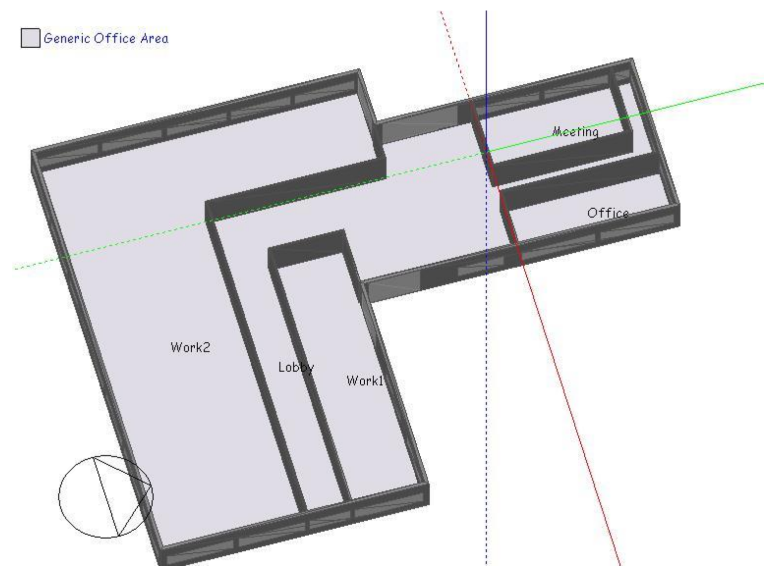


Energy Cost Analysis for the KWRP

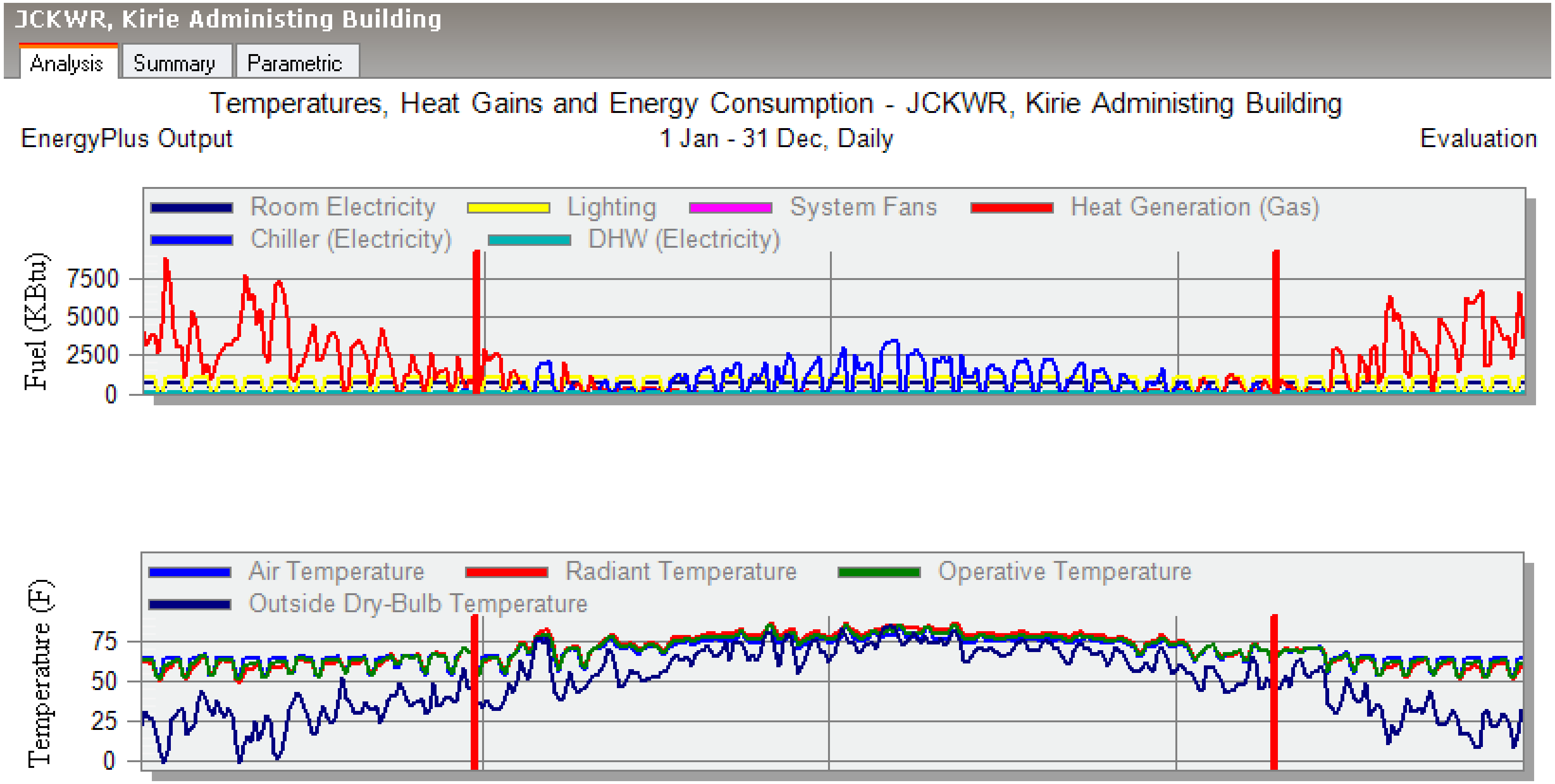








Energy Cost Analysis for the KWRP



Energy Cost Analysis for the KWRP Office Buildings (Residential Rates –Savings for Commercial Similar)

Design Builder Simulation Result:

End Uses

	District Cooling [kBtu]	District Heating [kBtu]
Heating	0. 00	390330. 03
Cooling	303577. 97	0. 00

For HVAC system:

Electricity in Chicago area is about $0.155/kWHr

Gas in Chicago area is about $1.07/therm

Use electricity for cooling, gas for heating:

	Therm	Utility Cost ($)
Gas	3903.30	4176.53
	KWHR	
Electricity	88910.40	13781.11
	TOTAL COST	17957.64

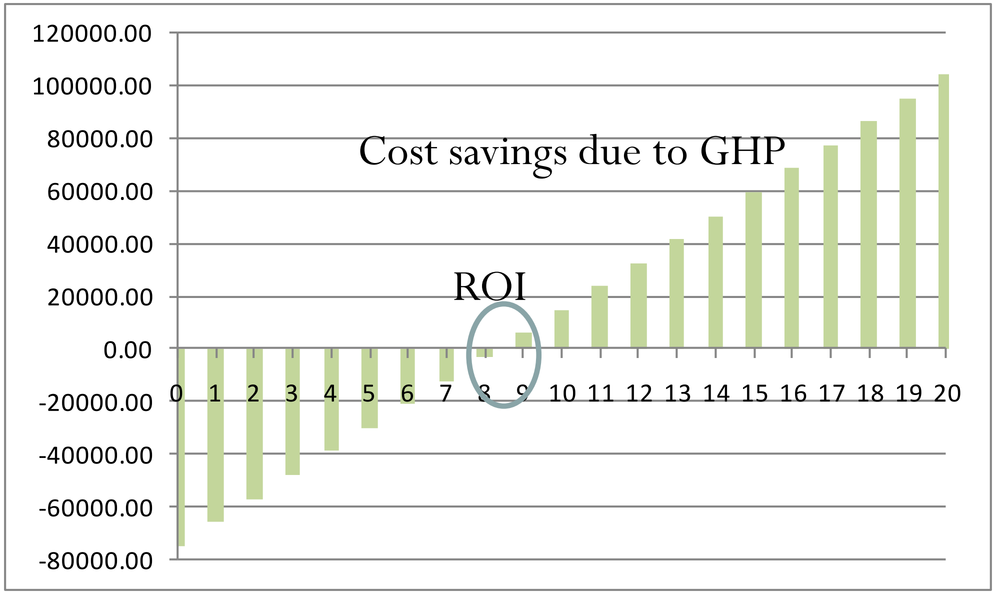
For GHP: Initial Investment: $1,500~2,000/ton including installation, major operation cost is from electricity consumption.

- For GHP (Lifetime)
  - Polyethylene ground loop ~ 100 years
  - Trane heat Pumps ~ 50 years
- For HVAC (Lifetime)
  - Air conditioning – 13 years
  - Furnace – 17 years
  - Maintenance cost

What is the Cost Recovery?

- 30 TON GEOTHERMAL HEAT PUMP: Cost and Installation including piping costs, installation costs, reservoir costs, etc were all considered to obtain a final figure of approximately $75,000 as total capital cost

	KWHR	Cost ($)	Saving/yr ($)	Saving %
GHP	**57989.25**	**8988.33**	**8969.31**	**49.95**



-- Return on Investment is about 8.5 years for GHP

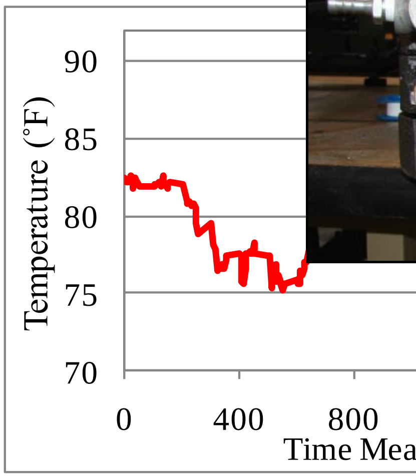
-- 50% reduction in energy costs

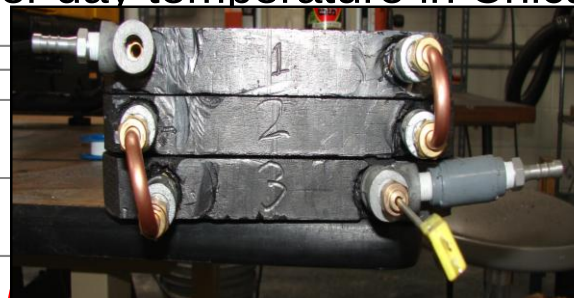
Cost Recovery for the administration building (use heat pump average C.O.P =3.5)
The Average Life of a System is 35 Years.

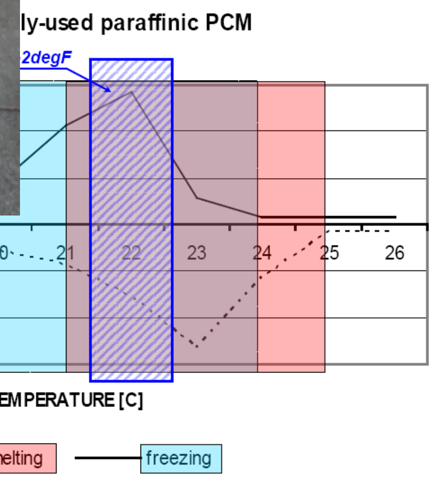
Future Plans–Include PCMs Unit

A typical summer day temperature in Chicago 2010

Multi-module PCMs energy storage system (front and side view)







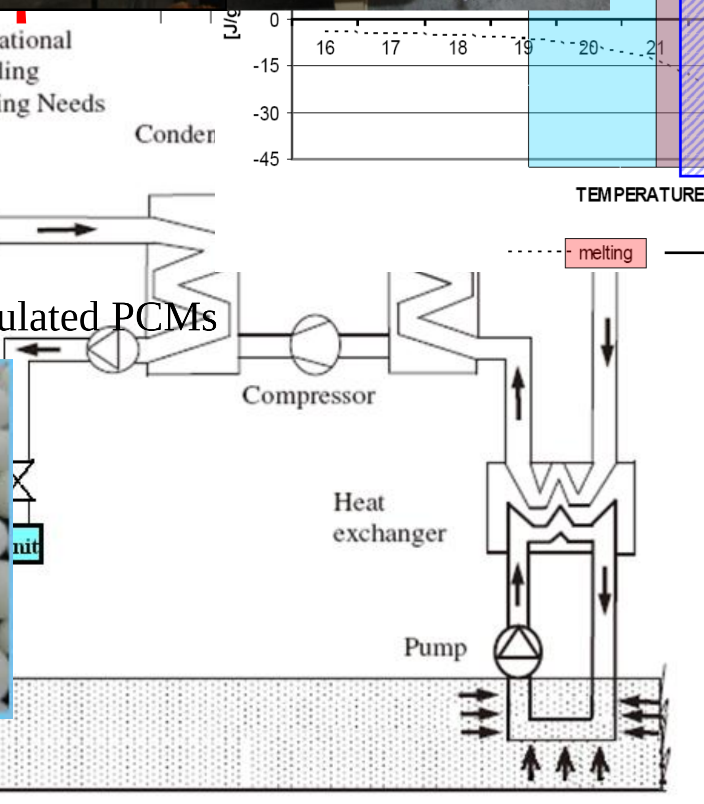


Image of commercial available encapsulated PCMs

Conclusions

- A GHP demonstration project is being evaluated at the Kirie WRP in order to determine the feasibility of harnessing energy from the effluent water.

- Both open and closed loop configurations will be evaluated. The demonstration system is expected to supply 20 percent of the energy needs at the plant.

- Once the demonstration systems has been successfully operated, the collected data can be used to design a complete system at this plant which would satisfy the entire energy needs for heating and cooling at substantially reduced cost.

- The design at the Kirie Plant could easily be applied to other facilities such as the Racine Street Pumping Station or the Egan WRP.

Thank you !